
Francis I. O'Brien

University of Windsor

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A STUDY OF DIAPTONUS LEPTOPUS S.A. FORBES, 1882.
(COPEPODA: CALANOIDA) IN A
TEMPORARY POND

BY
FRANCIS I. O'BRIEN

A Thesis
Submitted to the Faculty of Graduate Studies through the
Department of Biology in Partial Fulfilment of the
Requirements for the Degree of
Master of Science at the
University of Windsor

Windsor, Ontario, Canada

1971
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ABSTRACT

An ecological study of a temporary pond was carried out from March 4 to July 24, 1970 in Windsor, Ontario. Twice weekly samples were taken and selected physical and chemical parameters were measured.

Initially *Closterium* sp. was the dominant phytoplankter, but after May 26 the diatoms were dominant.

The dominant zooplankters were the copepods *Diaptomus leptopus* and *Cyclops bicuspidatus thomasi* and the cladocerans *Daphnia schodleri*, *Daphnia pulex* and *Moina rectirostris*. Zooplankton were enumerated using a Sedgwick Rafter counting chamber. A linear correlation was found between total calanoids and total cladocerans. Clutch size was found to decrease with increasing water temperature and evidence of suppression of reproductive activity of *Diaptomus leptopus* by the cladoceran population is indicated. Metasomal lengths of *D. leptopus* were smaller than those reported in the literature. The possible mechanisms of overwintering in the absence of winter eggs are discussed.
ACKNOWLEDGEMENTS

I would like to express my thanks to Dr. J.M. Winner, Biology Department, University of Windsor for his encouragement and constant advice in the research and preparation of this dissertation. Special thanks are extended to Dr. R.T. M'Closkey and Dr. M. Sanderson for their discussions and proof reading. The suggestions of Mr. D.K. Krochak, Dr. D.G. Wallen and Dr. G.L. Winner were greatly appreciated.

I am indebted to the Department of Geography for the use of the precipitation data of the University of Windsor, weather station.

The technical assistance of Mr. R. Kral, Mr. J.L. Mackenzie, Mr. P. Patrick and Miss M. McConnell was greatly appreciated.

I would like to acknowledge the financial aid of a Biology Department teaching assistantship for 1970-1971 and the financial assistance from the National Research Council grants of Dr. J.M. Winner.

Finally, I would like to thank Mrs. G. Birmingham for typing the manuscript.
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INTRODUCTION

Few limnological studies of temporary ponds can be found in the literature. Although the investigations of Mozly (1932), Røen (1957), Sawchyn and Hammer (1968), Hammer and Sawchyn (1968), Hartland-Rowe (1966) and Moore (1970) have provided some information on temporary pond species, data on single species is lacking.

In a preliminary study of a temporary pond in Windsor, Ontario, in 1969, the dominant zooplankton species were the Cladocera *Daphnia schröderi*, *Moina rectirostris*, the cyclopoid *Cyclops bicuspidatus thomasi* and the calanoid *Diaptomus leptopus*. An interest in *Diaptomus leptopus* occurring in permanent aquatic habitats, prompted an investigation of this isolated population under temporary pond conditions.


Following the egg stage calanoid copepods have twelve instars, the twelfth being the definitive adult. In most ecological studies on the fresh water calanoids, no attempt has been made to separate the naupliar and copepodid stages. They are usually either omitted or grouped together as total nauplii or total copepodids. Exceptions to this are the studies of Comita (1956) and Main (1962). Individual instars have been described by Dietrich (1915), Ewars (1930), Wuthrich (1948), and Humes (1955). More recently, Czaika and Robertson (1968)
examined the copepodid and adult morphology of several diaptomid species of the Great Lakes region.

The objectives of the present study were:-

1) to describe the life history of *Diaptomus leptopus* under temporary pond conditions, and

2) to attempt to elucidate the abiotic and biotic factors which determine the variables responsible for the establishment and maintenance of the population of *Diaptomus leptopus* under temporary pond conditions.
DESCRIPTION OF THE POND

The temporary pond discussed in this dissertation is located on the premises of the sanitary landfill area of the city of Windsor, Essex County, Ontario, approximately 200 meters west of Malden Road (83° 3' 36" West and 42° 16' 30" North), 590 feet (179.8 m) above sea level.

The area was described by Richards, Caldwell and Morwick (1949), and Oud (1970), as being partly Plainfield, partly Berrien sand and smooth clay overlying a Devonian limestone base. The area was primarily moulded by glaciation of the Pleistocene and the presence of Lake Maumee.

Water levels in the pond are maintained chiefly by surface runoff and ground seepage as there is no inlet or outlet.

The life of the pond is largely determined by the temperature and precipitation of the preceding summer and fall. Evaporation is usually sufficient to dry the pond with the onset of warm summer temperatures and low precipitation. The pond did not dry out in the summer of 1969, but it dried out by July 30 in 1970 and by June 18, 1971. The pond has a surface area of 0.0478 hectares and additional morphometric data can be found in Table 1. The dimensions given are estimated for high water levels and are continually changing as the pond is drying out, Fig. 2.

The dominant emergent vegetation Typha angustifolia L. completely surrounded the pond. Typha latifolia L., Alisma sp., and Juncus sp. were also present. No floating species were present. Hordeum jubatum (squirrel-tail grass) was present in the surrounding area.

Species of invertebrates associated with the temporary pond

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were the coleopteran *Dinuetes* sp., the hemipterans *Notonecta* sp. and *Gerris* sp. The odonate nymphs of *Enallagma* sp. were common. Aquatic mites were occasionally found in plankton samples as were the instars of *Chaoborus* sp. The fisher spider *Dolomedes triton* was observed on a few occasions. A large population of *Cambarus* sp. was also present.

The vertebrates included the painted turtle *Chrysemys picta*, *Rana piniens* and a *Bufo* sp. Young of the year of the northern fathead minnow, *Pimephales promelas promelas* were found in a few plankton samples but never in large numbers. These were probably introduced by birds.
MATERIALS AND METHODS

A sampling programme was initiated on March 4, 1970 and continued to July 24, 1970 when the pond dried up. The following physical, chemical and biological samples were taken twice weekly at 10.30 a.m. at a single station in the pond (Fig. 1). Air and water temperatures were determined by a mercury thermometer to the nearest 0.5 °C. Carbon dioxide, oxygen and pH were measured at the site using the Hach Chemical Company portable test kit for water analysis. Alkalinity, chloride as Cl⁻, copper, fluoride, hardness, iron, nitrogen, phosphate, silica, sulphate and turbidity were measured using the Hach Chemical Company, Water and Waste Water analysis as adapted for the Bausch and Lomb spectronic 20 and for titrametric procedures.

At the same time a 10 l quantitative plankton sample was taken with a 2 l calibrated pitcher and concentrated to 97 ml through a 28 μ aperture Wisconsin net. It was immediately fixed in 4% formalin (pH 7.4). Qualitative net samples were also taken at this time for reference. Plankton samples were examined in the laboratory using a Wild binocular compound microscope and a Reichart Visopan projection microscope. Zooplankton identification was based on Ward and Whipple's Freshwater Biology (in Edmondson, 1959). The copepods were examined according to the techniques of Wilson and Yeatman (1959) where identification is based mainly on the characteristics of the fifth leg and antennae and those of Czaika and Robertson (1968). Appendages were dissected in 80% lactic acid. Metasomal lengths were measured with an ocular micrometer and a calibrated Reichart Visopan projection microscope. A range of metasomal lengths was then drawn up for copepodid 1

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to copepodid 6 (abbreviated C 1 to C 6 in this thesis). Total lengths were measured in the case of nauplius 1 to 6 (abbreviated N 1 to N 6). A student's 't' test was then carried out between all six nauplii and all six stages of copepodid and between the sexes in C 4, C 5 and C 6, to test for significant differences in size.

A 1 litre sample was taken at the site for pigment extraction which was carried out after the methods of Richards with Thompson (1952). Concentration of chlorophyll a was calculated according to the formula of the SCOR/UNESCO working group on photosynthetic pigments (SCOR/UNESCO, 1966).

Dark bottle/light bottle productivity was based on a six hour incubation period in the pond. However, interference with bottles necessitated incubation in the laboratory in a Rigosha illuminated water bath. Gross primary production values were measured in the pond during the period March 28 to April 18, 1970, the remainder were measured in the Rigosha incubator. The technique involved the determination of oxygen after the incubation of a pair of standard 300 ml B.O.D. bottles, one of which is completely darkened. The illumination of the water bath was 400 foot-candles (Oud, 1970). The bottles were incubated for six hours when the study was initiated but this period was later reduced to two hours. After incubation the oxygen concentration was determined by the Hach modification of the Winkler method. The light and dark calculations were based on those of Cox (1967).
RESULTS

Physical Results

The physical results are summarized in Table 2 and plotted in Fig. 2.

Air temperature ranged from -0.5 °C to 29 °C with a mean of 18.9 °C and water temperature from 0 °C to 28 °C with a mean of 17.5 °C. After the thaw in mid-April water temperature followed air temperature closely.

The data of the University of Windsor weather station show the total precipitation from March 1, to July 31, 1970, to be 36.47 cms compared with 45.11 cms for the same period in 1969. Loss of water from the pond occurred with high temperatures, low precipitation and high evaporation (Fig. 2).

Turbidity (Fig. 2) ranged from 44 Jackson Units (J.U.) to a high of 620 J.U. just before the pond dried up. Turbidity values had a mean value of 150.8 J.U.

Chemical Results

A summary of chemical factors is shown in Appendix 1, Table 3 and Figs. 3, 4, 5, 6.

Dissolved oxygen concentrations ranged from 3.2 ppm to 16 ppm with a mean of 8.4 ppm (Fig. 3). The high levels were recorded March 21, May 39 and July 17, the latter was just before the pond dried out.

Free carbon dioxide (Fig. 3) ranged from 0 to 25 ppm and had a mean of 13 ppm.

The hydrogen ion concentration (Fig. 6) remained alkaline throughout the study and varied from 8.0 to 9.6 with a mean of 8.6
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<td>23.0</td>
<td>(16.3)</td>
<td></td>
<td>620</td>
</tr>
</tbody>
</table>

Fig. 2. Temperature, depth, precipitation and turbidity in temporary pond from March 4 to July 24, 1970.
Table 3. Mean ($\bar{x}$), variance ($s^2$) and standard deviation ($s$) of selected physical and chemical parameters in the temporary pond, 1970.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>N</th>
<th>$\bar{x}$</th>
<th>$s^2$</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Alkalinity (ppm)</td>
<td>36</td>
<td>147.5</td>
<td>4129.7</td>
<td>64.2</td>
</tr>
<tr>
<td>Carbon dioxide (free)(ppm)</td>
<td>36</td>
<td>13.1</td>
<td>20.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Total hardness (ppm)</td>
<td>36</td>
<td>210.6</td>
<td>4261.3</td>
<td>65.2</td>
</tr>
<tr>
<td>Total nitrogen (ppm)</td>
<td>37</td>
<td>0.8</td>
<td>1.06</td>
<td>1.03</td>
</tr>
<tr>
<td>Dissolved oxygen (ppm)</td>
<td>37</td>
<td>8.4</td>
<td>10.7</td>
<td>3.2</td>
</tr>
<tr>
<td>pH</td>
<td>36</td>
<td>8.6</td>
<td>0.52</td>
<td>0.72</td>
</tr>
<tr>
<td>Total phosphate (ppm)</td>
<td>33</td>
<td>0.26</td>
<td>0.04</td>
<td>0.2</td>
</tr>
<tr>
<td>Silica (ppm)</td>
<td>34</td>
<td>1.18</td>
<td>1.28</td>
<td>0.11</td>
</tr>
<tr>
<td>Sulphate (ppm)</td>
<td>36</td>
<td>62.4</td>
<td>625.7</td>
<td>25.0</td>
</tr>
<tr>
<td>Temperature (air) °C</td>
<td>37</td>
<td>18.9</td>
<td>83.7</td>
<td>9.1</td>
</tr>
<tr>
<td>Temperature (water) °C</td>
<td>37</td>
<td>17.5</td>
<td>77.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Turbidity (J.U.)</td>
<td>36</td>
<td>150.5</td>
<td>24212.5</td>
<td>155.6</td>
</tr>
</tbody>
</table>
Fig. 3. Dissolved oxygen, carbon dioxide, total alkalinity, total hardness concentrations in the temporary pond from March 4 to July 24, 1970.
Fig. 4. Copper, manganese, iron and fluoride concentrations in the temporary pond from March 4 to July 24, 1970.
Fig. 5. Total nitrogen, total phosphate, precipitation and sulphate concentrations in the temporary pond from March 4 to July 24, 1970.
Fig. 6. Chloride, pH, silica and total alkalinity concentrations in the temporary pond from March 4 to July 24, 1970.
Total alkalinity ranged from 20 ppm to 230 ppm with a mean of 147.5 ppm. Most of the alkalinity was due to bicarbonate, see Appendix 1. The lowest values for alkalinity were found during the first and last week of the study (Fig. 3).

Total hardness varied from 85 ppm to 454 ppm with a mean of 210.6 ppm. The general trends of total hardness and total alkalinity were similar, Fig. 3.

Other chemicals contributing significantly to the temporary pond system were total nitrate which ranged from 0.088 ppm to 4.413 ppm with a mean of 0.876 ppm. Total phosphate varied from 0.02 ppm to 0.53 ppm with a mean of 0.26 ppm. Silica ranged from 0.09 ppm to 4.2 ppm and had a mean of 1.18 ppm, and sulphate varied from 18.85 to 141 ppm with a mean of 62.4 ppm. Chlorine, copper, manganese, fluoride and iron values can be seen in Appendix 1 and Fig. 4,5,6.

Biological Results

Phytoplankton

The major phytoplankton species recorded are shown in Table 4. Quantitative phytoplankton counts are included although Chlorophyll a is used with cell number as an indicator of food availability. Closterium sp. was the dominant form from mid-March to the end of April but the diatoms were dominant after May 26.

Primary Productivity

Results of light and dark bottle measurements and of chlorophyll a extraction are shown in Appendix 3 and Fig. 7. Gross primary production (Fig. 7) ranged from 0 to 2439 mgC/m³/hour and had a mean
Table 4. List of major phytoplankton species identified from surface samples in the temporary pond. Classified-Prescott 1964.

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorophyta</td>
<td>Ulothrix sp.</td>
</tr>
<tr>
<td></td>
<td>Pediastrum sp.</td>
</tr>
<tr>
<td></td>
<td>Closterium sp.</td>
</tr>
<tr>
<td></td>
<td>Mougeotia sp.</td>
</tr>
<tr>
<td></td>
<td>Spirogyra sp.</td>
</tr>
<tr>
<td>Chrysophyta</td>
<td>Tabellaria sp.</td>
</tr>
<tr>
<td></td>
<td>Navicula sp.</td>
</tr>
<tr>
<td>Euglenophyta</td>
<td>Euglena gracilis</td>
</tr>
<tr>
<td></td>
<td>Klebs 1883</td>
</tr>
<tr>
<td></td>
<td>Strobomonas sp.</td>
</tr>
</tbody>
</table>
Fig. 7. Trends in total phytoplankton, gross primary production, chlorophyll $a$ and total euglenoids in the temporary pond.
TOTAL PHYTOPLANKTON

GROSS PRIMARY PRODUCTION

CHLOROPHYLL a

TOTAL EUGLENOIDS

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of 433.9. The high value was on July 21, three days before the pond dried out. This high value was attributed to the high diatom population of that time, see Fig. 7. Chlorophyll $a$ ($\text{mgC/m}^3$) varied from 1.01 to 127.0 and had a mean of 22.43. Chlorophyll $a$ were highest after June 11, where all values but one (June 21) were above the mean. These high values were again attributed to the high population of diatoms and possible release of grazing pressure by zooplankters, Fig. 7,8.

Zooplankton

The zooplankton species recorded are shown in Table 6 and the crustacea plotted in Fig. 8. With the exception of the Cyclopoida, the Calanoida were dominant from the period April 29 to June 18 with the exception of May 15 to June 5 where the Cladocera were most abundant. The dominant and only calanoid was Diaptomus leptopus and the most abundant cladoceran was Daphnia schrödleri.

**Life History of Diaptomus leptopus**

Diaptomus leptopus has a monocyclic univoltine life pattern in the temporary pond. The developmental time from Nauplius 1 to adult in the temporary pond is 4.6 weeks as determined from the plankton samples. The naupliar development required 12 days and the copepodid to adult development 20 days. The mature adults produced eggs from May 8 to June 18 which apparently did not hatch immediately as no evidence of a second generation of nauplii was found. This would suggest that 'resting eggs' were produced which in some way 'overwinter' in
Table 5. List of zooplankton species identified from surface samples (after Ward and Whipple, 1959).

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Aschelminthes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Rotifera</td>
</tr>
<tr>
<td>Order</td>
<td>Monogononta</td>
</tr>
<tr>
<td>S.Order</td>
<td>Ploima</td>
</tr>
<tr>
<td>Fam.</td>
<td>Brachionidae</td>
</tr>
<tr>
<td>S.Fam.</td>
<td>Brachioninae</td>
</tr>
<tr>
<td></td>
<td>Brachionus sp.</td>
</tr>
<tr>
<td></td>
<td>Keratella cochlearis Gosse</td>
</tr>
<tr>
<td>Fam.</td>
<td>Asplanchnida</td>
</tr>
<tr>
<td></td>
<td>Asplanchna sp.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Arthropoda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Crustacea</td>
</tr>
<tr>
<td>Order</td>
<td>Copepoda</td>
</tr>
<tr>
<td>S.Order</td>
<td>Calanoida</td>
</tr>
<tr>
<td></td>
<td>Diaptomus leptopus S.A. Forbes 1882</td>
</tr>
<tr>
<td>S.Order</td>
<td>Cyclopoida</td>
</tr>
<tr>
<td></td>
<td>Cyclops bicuspidatus thomasi</td>
</tr>
<tr>
<td>S.Order</td>
<td>Branchiopoda</td>
</tr>
<tr>
<td>Order</td>
<td>Cladocera</td>
</tr>
<tr>
<td></td>
<td>Daphnia pulex</td>
</tr>
<tr>
<td></td>
<td>Daphnia schüdleri</td>
</tr>
<tr>
<td></td>
<td>Moina rectirostris</td>
</tr>
<tr>
<td></td>
<td>Bosmina sp.</td>
</tr>
<tr>
<td>S.Class</td>
<td>Ostracoda</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Protozoa (after Barnes 1968)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.Phylum</td>
<td>Sarcomastigophora</td>
</tr>
<tr>
<td>Class</td>
<td>Rhizopodea</td>
</tr>
<tr>
<td>Order</td>
<td>Arcellinida</td>
</tr>
<tr>
<td></td>
<td>Difflugia sp.</td>
</tr>
<tr>
<td>Class</td>
<td>Phytomastigophorea</td>
</tr>
<tr>
<td>Order</td>
<td>Dinoflagellida</td>
</tr>
<tr>
<td></td>
<td>Peridinium sp.</td>
</tr>
</tbody>
</table>
Fig. 8. Population dynamics of total cladocera, total calanoida, total cyclopoida and total phytoplanckton in the temporary pond March 4 to July 24, 1970.
the mud of the pond until the following year. *Diaptomus leptopus* females produced eggs on May 8, three days after their initial appearance. Sexual activity of the female is shown in Table 6.

Calanoid nauplii are relatively easy to distinguish from cyclopoid nauplii and the development of *Diaptomus leptopus* is similar to that described for *Diaptomus siciloides* by Ewers (1930). I was unable to distinguish consistently between nauplius 1 and nauplius 2 and between nauplius 4 and nauplius 5 where the major diagnostic feature is the maturation of an appendage. For this reason naupliar stages 1 and 2 are grouped together as are nauplius 4 and 5. The size range for the naupliar stages of development is shown in Table 7.

Nauplii were first recorded on April 15 when stages 1 to 5 were present. No calanoid nauplii were present in the previous sample of April 11, indicating a developmental time of four days from egg to nauplius 5. Nauplius 6 first appeared on April 25, indicating a developmental time of 8 days from nauplius five to six by estimation between population peaks. The total time for naupliar development is 12 days, Table 9. The last calanoid nauplii to be recorded, occurred in the May 1, sample. At that time N4, N5 and N6 were present, indicating that eggs were no longer hatching. Naupliar abundance can be seen in Appendix 2 and Fig. 9.

Calanoid copepodids are recognised by the presence of long first antennae and their basic adult form. Wilson (1959) describes copepodid development as shown in Table 8. Sexual dimorphism of the fifth leg is first observed in copepodid 4, Fig. 10. The range of
Table 6. Sexual activity of female *Diaptomus leptopus*

<table>
<thead>
<tr>
<th>Date</th>
<th>percent of population ♀</th>
<th>percent ♀ with egg sacs</th>
<th>percent ♀ with spermato- phores</th>
<th>egg diameter (x̄) mm</th>
<th>Clutch size</th>
<th>T°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 12</td>
<td>52.2</td>
<td>8.95</td>
<td>4.8</td>
<td>0.1069</td>
<td>23.1¹</td>
<td>19</td>
</tr>
<tr>
<td>May 22</td>
<td>47.1</td>
<td>22.2</td>
<td>2.8</td>
<td>0.1208</td>
<td>10.5</td>
<td>23</td>
</tr>
<tr>
<td>June 16</td>
<td>63.6</td>
<td>62.2</td>
<td>10.2</td>
<td>0.1153</td>
<td>15.3</td>
<td>28</td>
</tr>
</tbody>
</table>

Shell size was 0.00162mm throughout the study. All eggs in May and June appeared morphologically the same.

¹ Standard deviation (S²), May 12, 8.3, May 22, 0.50, June 16, 2.2.
Table 7. Size ranges of nauplii of Diaptomus leptopus 't' test significant at 0.02 level.

<table>
<thead>
<tr>
<th>Group</th>
<th>Range (mm)</th>
<th>N</th>
<th>( \bar{x} )</th>
<th>( s^2 )</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>N 1 &amp; N 2</td>
<td>0.143-0.188</td>
<td>40</td>
<td>0.167</td>
<td>0.0001</td>
<td>0.013</td>
</tr>
<tr>
<td>N 3</td>
<td>0.201-0.234</td>
<td>30</td>
<td>0.220</td>
<td>0.0005</td>
<td>0.023</td>
</tr>
<tr>
<td>N 4 &amp; N 5</td>
<td>0.260-0.344</td>
<td>69</td>
<td>0.294</td>
<td>0.0007</td>
<td>0.026</td>
</tr>
<tr>
<td>N 6</td>
<td>0.377-0.390</td>
<td>25</td>
<td>0.383</td>
<td>0.0001</td>
<td>0.0135</td>
</tr>
</tbody>
</table>

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Table 8. Copepodid development of Calanoida (Wilson, 1959).

<table>
<thead>
<tr>
<th>Copepodid stage</th>
<th>Developed legs</th>
<th>Bud</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>legs 1,2</td>
<td>leg 3</td>
</tr>
<tr>
<td>2</td>
<td>1,2,3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>1,2,3,4</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>1,2,3,4,5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1,2,3,4,5</td>
<td></td>
</tr>
<tr>
<td>6 (adult)</td>
<td>1,2,3,4,5</td>
<td></td>
</tr>
</tbody>
</table>
Table 9. Duration of Stages of *Diaptomus leptopus*.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Respective peaks</th>
<th>Estimated duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N 1-N 2)-N 3</td>
<td>April 15-April 18</td>
<td>4 days</td>
</tr>
<tr>
<td>N 3-(N 4,N 5)</td>
<td>April 18-April 25</td>
<td>8 days</td>
</tr>
<tr>
<td>N 5-N 6</td>
<td>April 25-April 25</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12 days</td>
</tr>
<tr>
<td>N 6-C 1</td>
<td>April 25-April 29</td>
<td>5 days</td>
</tr>
<tr>
<td>C 1-C 2</td>
<td>April 25-April 29</td>
<td></td>
</tr>
<tr>
<td>C 2-C 3</td>
<td>April 29-May 1</td>
<td>3 days</td>
</tr>
<tr>
<td>C 3-C 4</td>
<td>May 1-May 1</td>
<td></td>
</tr>
<tr>
<td>C 4-C 5</td>
<td>May 1-May 12</td>
<td>12 days</td>
</tr>
<tr>
<td>C 5-C 6</td>
<td>May 12-May 12</td>
<td></td>
</tr>
<tr>
<td>Total duration N 1-C 6</td>
<td></td>
<td>32 days</td>
</tr>
</tbody>
</table>
Fig. 9. Population dynamics of nauplii, copepodids and adults of *Diaptomus leptopus* in temporary pond.
Fig. 10. Fifth legs of Diaptomus leptopus
(A) Copepodid four female x 309,
(B) Copepodid four male x 549,
(C) Copepodid five female x 192,
(D) Copepodid five male x 206.
metasomal lengths is shown in Table 10 and Fig. 11. Copepodid abundance is shown in Appendix 3 and Fig. 9. Copepodid 1 first appeared in the April 29 sample and was not present on May 12. This indicates that although some eggs may have hatched they did not reach the copepodid stage before the population died off (Fig. 9). Copepodids 1 and 2 had their population peaks on April 29. Copepodid 4 appeared on May 1 and had its peak on the same day. Copepodids 5 and 6 both appeared on May 5 and had their peaks on May 12, Appendix 3 and Fig. 9. The duration of instars is estimated from the time interval between peaks (Table 9).

Linear correlations were carried out on several aspects of the biological and chemical data. Total population numbers of Cladocera and total population numbers of Calanoida show a positive linear correlation \((r=0.539)\) which is just significant at the 5\% level for 18 degrees of freedom. The test between total populations of Cladocera and oxygen concentration also showed a slight positive linear correlation \((r=0.467)\) which was barely significant at the 5\% level. Tests between population numbers of Diaptomus leptopus and Daphnia schrödleri \((r=0.260)\), population numbers of D. leptopus and Daphnia pulex \((r=0.218)\), population numbers of D. leptopus and Moina rectirostris \((r=0.212)\), population numbers of D. leptopus and total alkalinity \((r=0.096)\), D. leptopus population numbers and chlorophyll \(a\) \((r=0.003)\), and total zooplankton numbers and chlorophyll \(a\) \((r=0.361)\) were not significant.
Table 10. Size distribution of adults and copepods of *Diaptomus leptopus*. 't' test shows $p < 0.02$. C 2-C 3 not significant.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Range (mm)</th>
<th>$\bar{x}$</th>
<th>$s^2$</th>
<th>$s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 1</td>
<td>30</td>
<td>0.325-0.453</td>
<td>0.395</td>
<td>0.0007</td>
<td>0.0272</td>
</tr>
<tr>
<td>C 2</td>
<td>30</td>
<td>0.468-0.600</td>
<td>0.523</td>
<td>0.2670</td>
<td>0.5160</td>
</tr>
<tr>
<td>C 3</td>
<td>30</td>
<td>0.624-0.736</td>
<td>0.664</td>
<td>0.0008</td>
<td>0.0297</td>
</tr>
<tr>
<td>C 4 (total)</td>
<td>30</td>
<td>0.720-0.940</td>
<td>0.824</td>
<td>0.0024</td>
<td>0.0499</td>
</tr>
<tr>
<td>male</td>
<td>15</td>
<td>0.720-0.940</td>
<td>0.821</td>
<td>0.0030</td>
<td>0.0553</td>
</tr>
<tr>
<td>female</td>
<td>15</td>
<td>0.760-0.860</td>
<td>0.828</td>
<td>0.0019</td>
<td>0.0436</td>
</tr>
<tr>
<td>C 5 (total)</td>
<td>36</td>
<td>0.900-1.100</td>
<td>1.001</td>
<td>0.0030</td>
<td>0.0548</td>
</tr>
<tr>
<td>male</td>
<td>24</td>
<td>0.900-1.000</td>
<td>0.968</td>
<td>0.0006</td>
<td>0.0264</td>
</tr>
<tr>
<td>female</td>
<td>12</td>
<td>1.000-1.100</td>
<td>1.068</td>
<td>0.0009</td>
<td>0.0310</td>
</tr>
<tr>
<td>C 6 (total)</td>
<td>72</td>
<td>0.980-1.124</td>
<td>1.150</td>
<td>0.0052</td>
<td>0.0713</td>
</tr>
<tr>
<td>male</td>
<td>30</td>
<td>0.980-1.100</td>
<td>1.007</td>
<td>0.0051</td>
<td>0.0227</td>
</tr>
<tr>
<td>female</td>
<td>42</td>
<td>1.040-1.240</td>
<td>1.150</td>
<td>0.0052</td>
<td>0.0713</td>
</tr>
</tbody>
</table>

Lengths measured were metasomal lengths.
DISCUSSION

Life History of *Diaptomus leptopus*

*Diaptomus leptopus* displays a monocyclic univoltine life cycle in the temporary pond. The developmental time (estimated from plankton samples) was 4.6 weeks from nauplius to adult. This is similar to the results of Hazelwood and Parker (1961) who reported a mean life cycle of 5.2 weeks in Kepple Lake, Washington, a permanent body of water. The developmental time in this temporary pond is very much shorter than the 7.2 weeks reported by Winner (1970) for an acid bog habitat, and 6-8 weeks for first generation development reported by Sawchyn and Hammer (1968) for a temporary pond in Saskatchewan. They found that when the pond refilled, a second generation took only three weeks to develop.

Adult females first produced summer or subitaneous eggs on May 8. There was no evidence, however, that these hatched during the study period since nauplii were not present in the pond after May 1. Only subitaneous eggs were produced by *D. leptopus* during the study period as indicated by their uniform morphology. Shell thickness was 0.0016mm, the same as reported by Winner (1970), who found that in a dystrophic bog environment, *D. leptopus* produced in addition to subitaneous eggs, a morphologically distinct overwintering egg.

The mean clutch size appeared to have an inverse relationship with temperatures: as the water temperature increased, the clutch size decreased, see Table 6. Sawchyn and Hammer (1968) found similar results in all diaptomids in their Saskatchewan study. Sawchyn and Hammer (1968)
and Winner (1970) found that the clutch size increased with lower fall temperatures. Sawchyn and Hammer (1968) also found that crowding apparently affects clutch size in that low populations of diaptomids tend to have larger clutch sizes. The low clutch size of *D. leptopus* on May 22 in this study may have been influenced by crowding effects, caused by the peak populations of the cladocerans, *Daphnia pulex* and *Daphnia saldleri* which occurred during that period as noted by Krochak (1971). Parker (1961) has shown, in laboratory studies, that a population of *D. pulex* suppresses the reproductive activity of *Eucyclops agilis* and has attributed this suppression to the physical presence of *D. pulex*, not to the presence of any metabolic products produced.

Naupliar development of *D. leptopus* was completed in an estimated 12 days during an average temperature of 16.5 °C. Comita (1953), found that naupliar development of *Diaptomus ashlandi* took 75 days when the temperature ranged from 4.5 to 13 °C. The shorter developmental time for *D. leptopus* is probably due to the higher prevailing temperature.

Copepodids developed in 20 days and adults were first found on May 5, three days before the first eggs were recorded, indicating a maximum of three days to attain sexual maturity.

In the present study the mean metasomal length of *D. leptopus* males was 1.007 mm. Winner (1970) reported a mean length of 1.34, 1.48 and 1.43 mm for adult males in Montague Bog for the years 1961, 1962, 1963 respectively. Comita (1968) reported a mean of 1.45 mm for adult males in his study. All of these data are larger than those found in the temporary pond and support Sawchyn and Hammer's (1968) contention.
that size is directly proportional to the stability of the environment.
The data of the present study and that of Winner (1970), Comita (1968) and Sawchyn and Hammer (1968) do not concur with the observation of Cole (1966), that metasomal lengths of diaptomids in temporary ponds are larger than those found in permanent ponds.

Sex ratios showed little variability in contrast to the findings of Winner (1970) who found that females dominated the population for the greater part of his study and Sawchyn and Hammer (1968) who found that males predominated in their investigation.

Adult and larval stages of the calanoid and cladoceran populations were absent by the end of June, although water was still present. The high temperature at this time ($\bar{x} = 24.9 \, ^\circ C$) may have had a deleterious effect on the populations. Turbidity was also very high at this time which would have affected light penetration, a factor which Hazelwood and Parker (1963) found to be negatively correlated with D. leptopus population size. Dissolved oxygen concentration would probably not be limiting in this study, since concentrations were still high when the pond was drying up.

Most calanoids are filter feeders and therefore are not species specific in terms of food selection. Parsons, LeBrassuer and Fulton (1967) however, have shown that they have certain size preferences. The phytoplankton in this study has shown a gradual increase in biomass with time and its peak towards the end of the study is probably due to the cessation of grazing pressure by the zooplankters. Initially the desmid Closterium sp. was dominant but after May 26 the diatoms became dominant and remained so throughout the study. Calanoids are known to feed on diatoms (Marshall and Orr, 1955a) and probably show a greater preference
for these than the larger Closterium sp. Bogatova (1965) reported that gut analysis of Eudiaptomus graciloides, consisted of as much as 87.8 percent blue green algae. He also found that this species selected smaller algal size than Daphnia hyalina, a very useful asset to the calanoid in avoiding direct food competition with this cladoceran. In the same study 78 percent of the gut contents of D.pulex was found to be composed of detritus. In the temporary pond a positive linear correlation was found between total Calanoida and total Cladocera which would indicate that these zooplankters do not compete for food.

Survival of planktonic crustacea in temporary ponds necessitates the production of an overwintering stage, either as an egg or larva. In this study D.leptopus did not produce resting eggs as described by Winner (1970). The survival mechanism of this calanoid population under temporary pond conditions is thus unknown. However, a number of survival mechanisms for copepod populations has been proposed in the literature. Gurney (1931) described a calanoid population in which only subitaneous eggs were produced and yet when the ponds dried up and later refilled, they were repopulated as though resting eggs were produced. Fairbridge (1945a) reports a similar instance in a population of Boeckella opaqua, which in culture only produced summer eggs that did not hatch until long after the females died. He suggests that these eggs could not survive dessication. Brewer (1964) has shown undifferentiated eggs of Diaptomus stagnalis were susceptible to cold temperatures, but could withstand warm temperatures and dessication. In the differentiated state they were resistant to cold temperatures but susceptible to warm temperatures and dessication. Sawchyn and Hammer (1968) suggest for D.leptopus that not
all eggs hatch in the following spring but some actually survive for
two years. This theory is based on a study of a pond which dried out
before a population of *D. leptopus* could mature and produce eggs. When
it was later refilled, it was inhabited with a new population of the
calanoid. They concluded from this that the population had to be
produced from eggs of the previous year. This may be a possible
mechanism for the repopulation of *D. leptopus* in the Windsor temporary
pond. Smyly (1967) has reported several cyclopoid genera overwintering
in fourth or fifth copepodid stage. This phenomenon has not been re­
ported in calanoids and none were found in mud samples of this pond.

Whatever the mechanism of survival is, *Diaptomus leptopus*
has the capacity to successfully populate an unpredictable environment.
SUMMARY AND CONCLUSIONS

1. An ecological study of Diaptomus leptopus was conducted from March to July, 1970 in a temporary pond in Windsor, Ontario.

2. Selected physical and chemical parameters were determined.

3. The dominant phytoplankters were initially Closterium sp. but diatoms dominated the population after May 26.

4. The dominant zooplankters were the copepods Diaptomus leptopus, Cyclops bicuspidatus thomasi and the cladocerans Daphnia schröderi, Daphnia pulex and Moina rectirostris.

5. Linear correlation was found between total Calanoida and total Cladocera.

6. Clutch size of Diaptomus leptopus was found to decrease with rising water temperature and evidence of suppression of reproductive activity of Diaptomus leptopus by the cladoceran population is indicated.

7. Metasomal lengths of adult male D. leptopus were smaller than those reported in the literature.

8. The possible mechanisms of overwintering in the absence of winter eggs are discussed.

In conclusion it is obvious that despite unfavourable conditions of a temporary pond, Diaptomus leptopus has adapted successfully in colonizing such an unpredictable environment.
# Appendix 1

## Chemical Analysis Summary

**Location**: Temporary Pond - Surface Sample

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### Alkalinity
- **Hydroxide**: 0 0 0 0 0 0
- **Carbonate**: 0 0 0 0 0 0
- **Bicarbonate**: 60 60 20 49 55 50
- **TOTAL**: 60 60 20 49 55 50

### Carbon Dioxide (Free)
- 20 5 15 10 0 15

### Chloride as Cl⁻
- 105 85 90 115 62 81

### Copper
- 0.13 0.48 0.03 0 0.21 0.03

### Fluoride
- 0.20 0.41 0 0 0 -

### Hardness
- **Calcium**: 150 170 120 104 209 282
- **Magnesium**: 90 60 75 179 249 116
- **TOTAL**: 240 230 195 283 454 398

### Iron
- 3.9 3.4 5.9 7.8 2.4 4.8

### Manganese
- 0.51 0.40 0 0 0 0

### Nitrogen
- **Nitrate**: 1.496 1.232 2.948 4.05 1.98 2.73
- **Nitrite**: 0.0 0.003 0 0 0 0
- **TOTAL**: 1.496 1.235 2.948 4.05 1.98 2.73

### Dissolved Oxygen
- 5 6 9 13 16 14

### pH
- 8.6 8.9 9 9.2 9.6 9.5

### Phosphate
- **Ortho**: 0 0.12 0.21 - 0.11 -
- **Meta**: 0.32 0.28 0.27 - 0 -
- **TOTAL**: 0.32 0.40 0.48 - 0.11 -

### Silica
- 1.5 1.0 1.0 0.97 0.74 1.14

### Sulphate
- 50.2 72 77.5 54 32 141

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### Appendix 2.

**Chlorophyll a (mgC/m³, \(x = 22.4\))**  
**Gross primary production (mgC/m³/hour, \(x = 433.9\))**

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Appendix 3. Abundance of *Diaptomus leptopus*

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LITERATURE CITED


VITA AUCTORIS

Born:

Elementary Education:

Secondary Education:
1960-1965 Colaiste Chriost Ri., Cork, Ireland.

University Education:

Scientific Societies:
American Society of Limnology and Oceanography
Freshwater Biological Association
The Marine Biological Association of the United Kingdom